

SMOLT MONITORING IN THE LAGUNITAS CREEK WATERSHED – 2021

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In association with the National Park Service

September 2021



Acknowledgements

Marin Water would like to thank the Gallagher family for granting us access onto their property to conduct this monitoring.

Cover image: The Lagunitas Creek rotary screw trap being checked by the Watershed Stewards Program members.

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EXECUTIVE SUMMARY

Downstream migrating salmonid smolts were sampled using a rotary screw trap (RST) in lower Lagunitas Creek, near Point Reyes Station (Figure 1). Smolt monitoring has been conducted annually since 2006 at that location, with the exception of 2020, when the pandemic prevented monitoring. From late March through the end of May the trap was monitored cooperatively by staff and volunteers from Marin Water and the Watershed Stewards Program (WSP). In addition, a smolt trap was operated on Olema Creek by National Park Service (NPS) staff.

In 2021 the RST was operational for 50 days. It was disabled for 16 days (eight weekends) between March 24 and May 28. For the season, a total of 4,422 Coho Salmon smolts were captured and 7,684 (± 615) Coho Salmon smolts were estimated to have emigrated past the trap. This was a somewhat below average emigration. In the fall of 2020, 21,886 Coho Salmon fry were estimated to reside upstream of the RST, yielding an exceptionally low winter survival rate of 35%. Coho Salmon smolt emigration from Olema Creek was not estimated in time to include in this report.

A total of 316 steelhead smolts were captured at the RST and an estimated 722 (\pm 108) steelhead smolts emigrated past the trap. This was by far the smallest steelhead smolt estimate on record. By contrast, the Chinook Salmon emigration was the second-highest to date. The RST captured 1,759 Chinook Salmon smolts and 3,691 (\pm 388) were estimated to have migrated past the trap.

INTRODUCTION

Lagunitas Creek is a regionally important coastal stream for Coho Salmon (*Oncorhychus kisutch*) and steelhead (*O. mykiss*), with recent Coho Salmon escapement estimates averaging approximately 500 individuals, and available data suggest that steelhead runs are similar in size. Chinook Salmon (*O. tshawytscha*) also spawn in Lagunitas Creek and smolts have been observed in most years.

Marin Water has conducted annual smolt surveys on Lagunitas Creek since 2006, as well as in 1983, 1984 and 1985. Summer and fall electrofishing surveys for juvenile Coho Salmon and steelhead were conducted in Lagunitas Creek starting in 1970 and annually since 1993. Since 2012 juvenile Coho Salmon captured during these surveys have been implanted with passive integrated transponder (PIT) tags. This represents one of the longest data records for juvenile salmonids in coastal streams of California. Surveys have been conducted cooperatively between Marin Water, the California Department of Fish and Wildlife (CDFW), the National Park Service (NPS), the Marin Resource Conservation District, the Watershed Stewards Program (WSP), and the Salmon Protection and Watershed Network (SPAWN). Systematic Coho Salmon adult spawner surveys began in 1982 and have been conducted annually since 1995. Since the early 1980s, stream flows in Lagunitas Creek have been monitored daily by United States Geological Survey gages located in Samuel P. Taylor State Park and near Point Reyes Station. A separate

gage is maintained by Marin Water on San Geronimo Creek. Water temperature has been monitored continuously since the early 1990s. Lagunitas Creek streambed conditions are monitored annually and salmonid habitat is quantified approximately every five years.

This project is being conducted in collaboration with NPS, which conducts similar monitoring surveys in Olema Creek. NPS has monitored salmonid smolt emigration from Olema Creek since 2004, and smolt monitoring was conducted on a tributary to Olema Creek between 1998 and 2004.

Smolt monitoring in the Lagunitas Creek watershed is intended to answer the following questions:

- What are the trends in Coho Salmon and steelhead smolt abundance?
- What are salmonid overwinter survival rates, what factors influence those rates, and do those rates differ between subwatersheds?
- What are Coho Salmon marine survival rates and how do these rates compare to other populations in the region?

METHODS

Lagunitas Creek Monitoring

A rotary screw trap (RST) with a five-foot diameter cone was installed on March 23, 2021 in lower Lagunitas Creek, approximately 2.1 miles above the Highway 1 Bridge in Point Reyes Station, and was operated for 50 days. The trap was situated in a pool directly downstream of a small bedrock cascade, and was in the same location as has been used since 2006. The bedrock cascade concentrates enough flow to operate the RST in the otherwise low gradient reach of the creek.

The RST was disabled from Friday afternoons to Sunday mornings during all but one week. The trap remained operational during the weekend of April 10-11 in anticipation of higher captures of Coho Salmon during the new moon. Plywood baffles were installed in front of the cone on April 2 to increase the cone rotation speed and improve trap efficiency. At the start of each day trap function was visually inspected and the rotation speed of the trap cone was recorded. The trap was occasionally realigned relative to the cascade to maintain cone speeds in the target range of three to eight revolutions per minute (RPM). A qualitative description of debris removed from the live box was recorded daily. Each day, captured fish were removed from the trap and identified by species. Salmonid smolts and parr were checked for marks such as fin clips, visually inspected for signs of smoltification, measured, weighed, allowed to recover, and then released approximately 200 m downstream of the point of capture. Coho Salmon smolts were scanned for passive integrated transponder (PIT) tags, implanted the previous fall. Steelhead at least 130 mm in length were generally called smolts, although some fish displaying characteristics intermediate between parr and smolts (e.g., some loss of scales, some silver color, fading parr marks, etc.) were classified as "transitional." These transitional steelhead

could not be assumed to be emigrating and were not included in the smolt estimate. Coho Salmon were classified as fry, transitionals, or smolts based on the degree of smolt characteristic development. Young-of-the-year Coho Salmon displaying smolt characteristics (e.g., silvery appearance) were classified as smolts. All Chinook Salmon were assumed to be emigrating and classified as smolts. Downstream migrating fry of all species that were less than 40 mm long were tallied but not measured or weighed. Adult steelhead that appeared unspawned were released upstream of the bedrock cascade. Spawned steelhead (kelts) were immediately released off the trap.

The proportion of migrating fish captured each week (trap efficiency) was determined by recapturing previously marked fish. For coho and Chinook, up to 20 smolts per day were given a fin clip unique to the week (Table 1). Up to 20 steelhead smolts per day were implanted with PIT tags. Marked fish were released approximately 300 m upstream. Some of these fish were subsequently recovered at the trap a second time and served as the basis for calculating trap efficiencies.

Week	Date	Mark Applied
1	March 22 to March 28	lower caudal clip (LC)
2	March 29 to April 4	dorsal & lower caudal clip (DLC)
3	April 5 to April 11	lower caudal and anal fin clip (LCAC)
4	April 12 to April 18	lower caudal clip (LC)
5	April 19 to April 25	dorsal & lower caudal clip (DLC)
6	April 26 to May 2	lower caudal and anal fin clip (LCAC)
7	May 3 to May 9	lower caudal clip (LC)
8	May 10 to May 16	dorsal & lower caudal clip (DLC)
9	May 17 to May 23	lower caudal and anal fin clip (LCAC)
10	May 24 to May 26	lower caudal clip (LC)

 Table 1. Marking schedule at the Lagunitas Creek smolt trap, 2021

Marin Water operates a PIT tag antenna upstream of the RST, primarily to detect PIT-tagged coho smolts and investigate rates of overwinter survival in different parts of the Lagunitas Creek watershed. In 2020, 370 juvenile Coho Salmon were implanted with PIT tags. In 2021 280 steelhead smolts and 43 steelhead of other age classes were implanted with PIT tags during smolt monitoring.

Olema Creek Monitoring

NPS staff operated a pipe/fyke trap on Olema Creek, based on a design used by CDFW on the Noyo River (Gallagher 2000). The trap was checked daily, and no more than 30 Coho Salmon

smolts (or up to 50% of the catch that day) were anesthetized with MS-222 (Tricaine Methanesulfonate) and marked with PIT tags. Marked smolts were released immediately after recovering from anesthetization at a predetermined site approximately 100 m or at least three habitat units above the trap site. After being measured, all recaptured smolts and unmarked smolts were released immediately in low velocity areas below the trap. Studies using similar methods of marking and tagging have demonstrated little marking mortality (Greis and Letcher 2002) and a study using the same trapping methodology on five northwestern California streams revealed that trap mortality was less than one percent for smolts and less than three percent for fry (Manning 2001).

Salmonids were identified to species and life stage (fry, parr, smolt, or adult) prior to being measured. Coho and steelhead that are less than one year old and can be identified by the presence of distinct parr marks and small body size were categorized as Young-of-Year (YoY). Age 1+ steelhead and Coho Salmon were separated into the following morphological categories: 1+ (older than one year in age, parr marks present, only used for steelhead) or smolt (faint or absent parr marks, silver body, deciduous scales, black fin margins). A random sub-sample of up to ten Coho Salmon smolts and steelhead parr and smolts were measured to the nearest millimeter (fork length), and weighed to the nearest 0.01 g using an electronic scale. All fish that were anesthetized and marked were also measured and weighed. Any adult steelhead encountered in the trap were released downstream immediately without being measured. Random sub-samples of ten Coho Salmon YoY and ten steelhead YoY were measured daily and individuals greater than 40 mm were weighed to the nearest 0.01 g using an electronic scale. Up to ten individuals of each non-salmonid species were also randomly selected, measured, and weighed. Sub-samples were obtained by taking blind scoops out of the holding bucket with a small aquarium dip net. After processing, each fish was placed in an aerated recovery bucket, keeping larger sculpin in separate buckets to avoid predation on smaller fish. Fish in the recovery bucket were monitored to ensure sedated fish recover fully before being released.

In addition to smolt trapping, a PIT tag antenna array was installed upstream of the Olema Creek smolt trap (Figure 1). For more detailed descriptions of smolt trapping methods, please refer to SOP (standard operating procedure) 3, SOP 4, SOP 6, SOP 9, and SOP 11 of the San Francisco Bay Area Network Salmonid Monitoring Protocol version 4.0 (Reichmuth et al. 2010).

Data Analysis

The efficiency of the Lagunitas Creek rotary screw trap and populations of Coho and Chinook Salmon and steelhead smolts were estimated using Darroch Analysis with Rank Reduction (DARR) 2.0.2 software (Bjorkstedt 2005, 2010) from mark-recapture data. The DARR 2.0.2 software was developed to allow populations of downstream migrants to be estimated using mark-recapture data, particularly in small watersheds. This program applies a set of algorithms to stratified mark-recapture data to produce an abundance estimate while defining the variability in capture probability and the distribution of recaptured individuals within the strata.

RESULTS

Lagunitas Creek Rotary Screw Trap

The Lagunitas Creek RST captured 4,422 Coho Salmon smolts (Table 2) and 779 young-of-theyear Coho Salmon. An estimated 7,684 Coho Salmon smolts emigrated from Lagunitas Creek during the monitoring period. The highest estimated passage occurred during the week of May 3 with 4,700 Coho Salmon smolts passing through and around the RST (Figure 2). The highest catch for a single day occurred on May 5 when 445 Coho Salmon smolts were captured. The weekly trap efficiency for Coho Salmon smolts varied from 20% to 87% (mean 55%) (Figure 3). Coho Salmon smolts averaged 105 mm fork length (FL) and weighed an average of 12.2 g.

The RST also captured 316 steelhead smolts, 503 fry, five adults, and 218 parr and transitionals. An estimated 722 steelhead smolts emigrated in 2021, with 140 smolts emigrating during the week of April 12. The peak catch of 21 steelhead smolts occurred on April 15. The trap efficiency for steelhead varied between 29% and 56% (mean 38%). Steelhead smolts averaged 176 mm in fork length and weighed an average of 55.3 g.

During the monitoring period 1,759 Chinook smolts were captured and 3,691 smolts were estimated to emigrate from Lagunitas Creek. Peak emigration occurred during the week of May 17 when an estimated 1,203 Chinook passed through and around the RST. The peak of 134 Chinook smolts was caught on May 14. Trap efficiency for Chinook varied between 35% and 70% (mean 48%). The average length of Chinook smolts was 68 mm, which was by far the smallest on record. The average weight was 3.5 g. A single Age 1+ Chinook was observed in 2021.

Non-salmonid fish species included the following native and non-native species, in order of abundance: Southern Coastal Roach (*Hesperoleucus venustus subditus*), sculpin spp. (*Cottidae*), Threespine Stickleback (*Gasterosteus aculeatus*), Pacific Lamprey (*Lampetra tridentata*), Golden Shiner (*Notemigonus crysoleucas*), Sacramento Sucker (*Catostomous occidentalis*), and Yellowfin Goby (*Acanthogobius flavimanus*). The season was notable for the very low abundance of non-native fish and the complete absence of centrachids (bass family). Non-fish captures included a record 609 California Freshwater Shrimp (*Syncaris pacifica*), Signal Crayfish (*Pacifastacus leniusculus*), and a single Western Pond Turtle (*Actinemys marmorata*).

Lagunitas Creek PIT Tag Antenna

During the summer of 2020 PIT tags were implanted into 372 juvenile Coho Salmon. A new PIT tag antenna was also installed a short distance upstream of the smolt monitoring site. The antenna detected 115 (31%) of the tagged coho (Table 3).

Veer	Survey	Survey	Coho S	Salmon	Steel	head	head Chinook	
Year	start date	end date	Observed	Estimated	Observed	Estimated	Observed	Estimated
2006	21 March	9 June	1,342	5,946 (±1,570)	308	6,949 (±6,133)	237	504
2007	15 March	30 May	611	2,776 (±692)	475	3,632 (±2,066)	775	2,445
2008	18 March	5 June	2,532	6,101 (±780)	449	1,134 (±259)	0	0
2009	10 March	5 June	3,150	5,711 (±461)	646	2,041 (±537)	0	0
2010	17 March	27 May	631	2,129 (±480)	651	3,867 (±1,419)	0	0
2011	1 April	20 May	1,684	3,300 (±470)	829	3,753 (±941)	0	0
2012	26 March	31 May	4,339	8,315 (±1,372)	251	1,991 (±1,252)	0	0
2013	19 March	7 June	4,942	7,479 (±504)	684	1,876 (±380)	0	0
2014	11 March	4 June	8,415	15,055 (±1,974)	448	1,720 (±478)	1,229	2,011 (±241)
2015	19 March	9 June	7,373	10,643 (±596)	814	2,699 (±594)	2,005	3,376 (±382)
2016	16 March	24 May	3,428	9,719 (±2,225)	371	4,396 (±3,099)	191	833 (±370)
2017	14 March	26 May	5,550	29,306 (±11,286)	524	3,164 (±1,313)	925	2,224 (±425)
2018	30 March	25 May	4,883	7,812 (±715)	536	1,879 (±576)	1,509	4,407 (±1027)
2019	20 March	16 May	4,652	11,246 (±2,164)	486	3,827 (±1,985)	792	2,217 (±335)
2021	24 March	28 May	4,422	7,684 (±615)	316	722 (±108)	1,759	3,691 (±388)

Table 2. Estimated smolt emigration from Lagunitas Creek, 2006-2021.

Table 3. PIT-tagged Coho Salmon detections

Tagging Location	Fish Tagged in 2020	Antenna Detections	Antenna Detection Rate	RST Detections	Total Detections	Total Detection Rate
Lagunitas Creek	120	45	38%	28	46	38%
San Geronimo Cr.	194	58	30%	26	58	30%
Devil's Gulch	58	11	19%	5	11	19%
All	372	115	31%	60	115	31%

DISCUSSION

Sampling conditions and emigration timing

The spring of 2021 was exceptionally dry, with less than 0.5" of rain during the monitoring period and no high flows to disrupt trap operation. The cone rotation speed remained within the target range of three to eight revolutions per minute (RPM) except for five days with reduced RPM. Catches of all three salmonid species started at low levels and increased during the first weeks of monitoring (Figure 2). This suggests that monitoring began early enough to capture the early phases of smolt emigration. By the end of the monitoring period the steelhead outmigration was complete, daily coho catches were low, and Chinook catches were in decline. While substantial numbers of Chinook Salmon smolts may have emigrated after monitoring ceased, this year's monitoring successfully captured the bulk of the coho and steelhead outmigrations.

As has been observed in previous years, the lunar cycle played an important role in migration timing. Steelhead catches peaked (albeit at a very low level) on April 15, four days after the new moon (Figure 2). During the April new moon the RST was operated seven days per week in anticipation of a Coho Salmon migration pulse that unfortunately did not materialize. Catches of coho peaked on May 5 and catches of Chinook peaked on May 14, six days before and three days after the new moon, respectively.

Age and size of salmonids

In 2021 the age and level of smoltification of captured Coho Salmon was fairly obvious and did not strongly influence the estimated size of the outmigration. Age 1+ Coho Salmon smolts were easily distinguishable by size from young-of-the-year (YOY) Coho Salmon until the last week of monitoring, when the size gap between these age classes disappeared. Relatively few (1%) of coho were classified as "transitional," and almost all of these were age 1+ fish that lacked strong evidence of smoltification. The exclusion of these fish from the smolt count had minimal impact on the population estimate. We identified 24 (presumably) age 2+ coho smolts, although these were smaller than age 2+ coho seen in previous years and the size gap between these and younger fish was indistinct (Table 4).

Despite establishing a minimum steelhead smolt length of 130 mm, fish appearance played a significant role in classifying steelhead smolts. Of the 351 steelhead at least 130 mm in length, 13% were classified as either parr or transitionals based on appearance. By classifying some larger fish as non-smolts and not classifying any age 1+ fish as smolts we may have slightly underestimated the size of the steelhead smolt outmigration.

Smolt abundance trends and implications for winter survival

The 2021 Coho Salmon emigration from the Lagunitas Creek watershed was somewhat smaller than average but similar to the estimate from three years earlier (Figure 4). Of the 21,886 juvenile Coho Salmon estimated to reside upstream of the Lagunitas smolt trap in 2020, only 35% appear to have survived through the winter. The 31% detection rate of PIT tagged coho

					Coho					
Week:	1	2	3	4	5	6	7	8	9	
Dates	3/21 3/27	3/28 4/3	4/4 4/10	4/11 4/17	4/18 4/24	4/25 5/1	5/2 5/8	5/9 5/15	5/16 5/22	
Length (mm)	Age	0+								
< 40	15	18	25	12	1	1				
40-44			1							
45-49		1	1			2		1		
50-54			1	2			1		1	
55-59			1		2	2		3		
60-64	Age '	+	1	2	4	3	5	1	2	
65-69					2	4	3	3	5	
70-74	1				1	1		1	3	
75-79	1						1	1	2	
80-84	2		5	2					4	
85-89	8	3	8	4		3	1		1	
90-94	8	3	16	15	7	2	2	5	8	
95-99	3	4	22	21	7	6	16	16	22	
100-104	2	2	16	15	27	22	35	32	31	
105-109	1	2	4	19	19	28	31	25	21	
110-114	1		7	18	17	21	16	15	9	
115-119	1		1	8	10	13	13	9	8	
120-124		1		5	4	4	4	4		
125-129		1		5	2	4		2	2	
130-134		2	2	1		3		1		
135-139		1		3	1	2		1		
140-144	Age	2+		2	2	1	2			
145-149	•					1				
150-154			1						1	
155-159										
160-164										
165-169										
170-174										
175-179										
180-184										
185-189										
190-194										
195-199										
200+										
Totals										
Age 0+	15	19	30	16	10	13	10	10	18	15%
Age 1+	28	14	79	112	94	106	118	110	106	82%
Age 2+	0	5	3	6	3	4	2	0	1	3%
Age 3+	0	0	0	0	0	0	0	0	0	0%

Table 4. Salmonids captured in the Lagunitas Creek rotary screw trap by length and week, 2021.

			St	eelhe	ad				
1	2	3	4	5	6	7	8	9	
3/21	3/28	4/4	4/11	4/18	4/25	5/2	5/9 5/15	5/16	
	4/3 0+	4/10	4/1/	4/24	J/ I	0/0	0/10	J/22	
Age	0.	160	33	53	9	96	7		
				1			2	1	
			1	1	1		3	1	
	1			2	1	2	1	1	
	4.			2	63	3		2	
Age	1+			2	5	2		2	
		1		1		1			
						1		1	
					Ļ				
4	1	0				ļ			
I		2	1	1			1		
		2		1					
1		-	1					1	
		3	-		-				
1		1	1		1		4	1	
1	Age	2+	1	1			T		
I		1		1	2				
		•	2		1				
3	2		2		5	2			
1	1	3	2	3	2	3			
~	3	7	4	2	3	1		1	
2	ა ა	/ 5	ა ი	/ م	10 0	4	1		
2	1	4	9	11	9 4	2 1			
2	5	4	10	9	7	3			
	1	2	11	5	4	1			
4	1	3	8	6	4	1			
Age	3+ 3	1	4	4	2				
2	2	(10 11	3	2	1			
3	2	9 4	11	3 4	ו 3				
5	0	7		+	5	I			
0	0	160	34	59	20	106	13	8	51%
2	1	11	4	2	1	0	2	2	3%
16	19	36	64	57	56	19	1	1	35%
10	14	21	28	7	3	0	0	0	11%

		Chinook								
Week:	1	2	3	4	5	6	7	8	9	
Length (mm)	Age 01	ŀ								
< 40	5	2	6							
40-44										
45-49			1	3	1			1	1	
50-54		1	5	3	8	2	2	1		
55-59	1	1	7	7	6	14	10	9	2	
60-64		4	13	8	14	28	33	9	13	
65-69			1	13	9	25	20	27	24	
70-74			1	4	11	18	21	27	32	
75-79					4	6	5	16	19	
80-84					1	5	9	10	10	
85-89	Age 1+		1				1	1	1	
90+								1		
Totals	6	8	35	38	54	98	101	103	102	

supports this survival estimate. The record low steelhead smolt estimate suggests a winter survival rate of less than 15% from the 4,700 age 1+ steelhead estimated in 2020. Low rates of both coho and steelhead winter survival may be due to a single cause.

Poor survival in past winters appeared related to the timing or magnitude of winter storms, but this year's dry winter (the second-driest in 142 years) provided an alternative explanation. This winter featured an extraordinarily long dry spell (62 consecutive days of stream flows below 80 cfs). The winter of 2019-20 had a similarly long dry spell and similarly poor survival. In 2016-17 coho survived at twice the rate of this year, and no more than ten days passed between significant runoff events.

A possible mechanism for poor salmonid survival during long periods of clear water is increased predation by Common Mergansers (*Mergus merganser*), which are frequently seen in Lagunitas Creek during the winter. Common Mergansers are the primary avian predators of juvenile salmonids and smolts in some West Coast watersheds (Stephenson and Fast 2005, Wood 1987). A potential method for increasing winter survival of both Coho Salmon and steelhead may be to accelerate Marin Water's long-term program of using large wood to create complex shelter throughout Lagunitas Creek. This would have the combined benefits of creating the pool habitat juvenile coho need during the summer and the escape cover both coho and steelhead need during the winter.

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Figure 1. Smolt monitoring locations in the Lagunitas Creek watershed.



Figure 2. Lagunitas Creek smolt emigration, lunar cycle, and stream flow.



Figure 3. Weekly trap efficiency and Lagunitas Creek stream flow.



Figure 4. Lagunitas Creek smolt emigration estimates.

Note: The coho recovery target assumes an ocean survival rate of at least 5%, resulting in 2,600 adult returns.